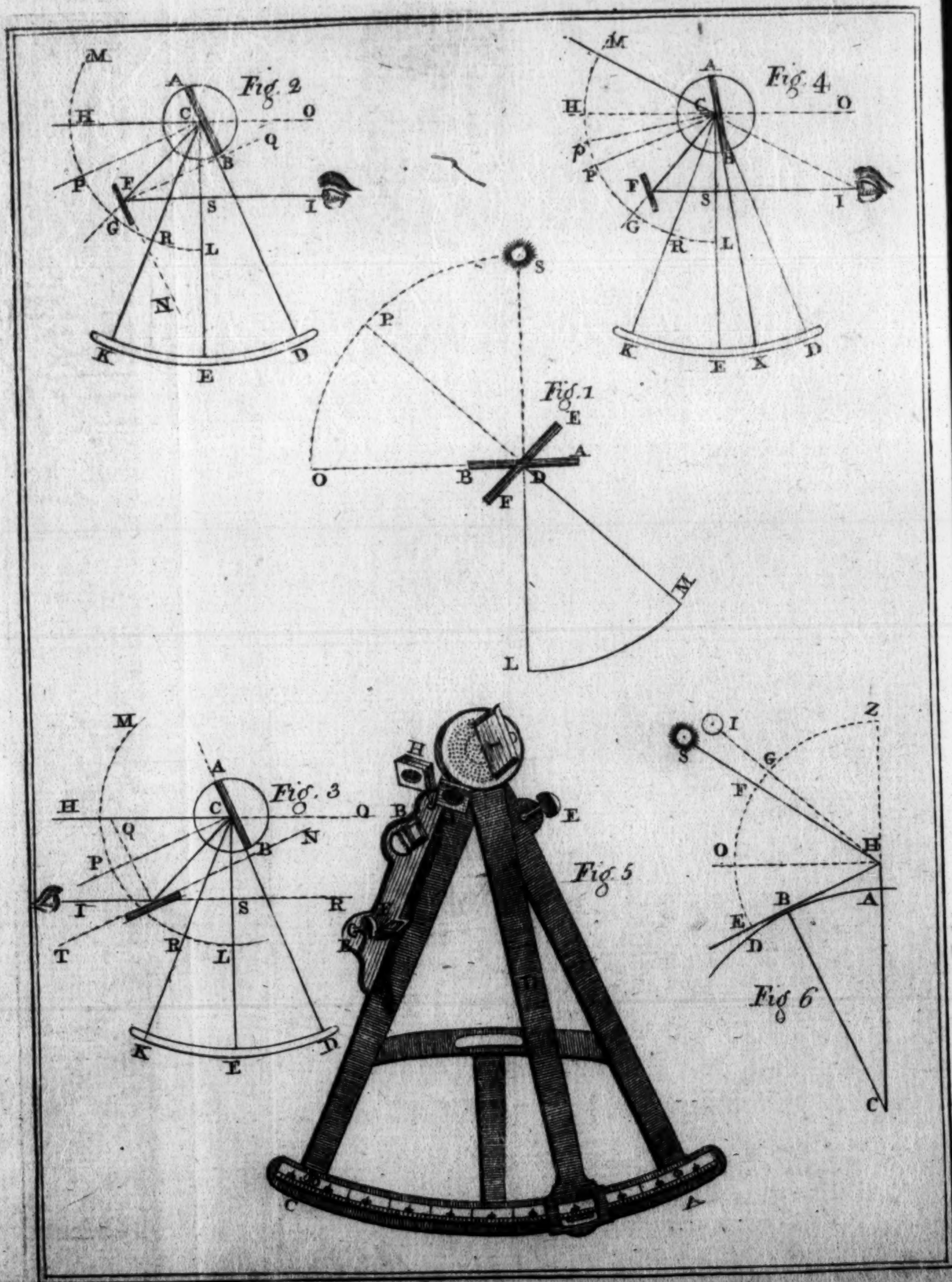
Fig. 2
Fig. 4
Fig. 1
Fig. 3
Fig. 5
Fig. 6

THE THEORY AND CONSTRUCTION OF HADLEY'S QUADRANT DEMONSTRATED:

AND ALSO

All the neceſſary DIRECTIONS given for ADJUSTING the GLASSES,

And uſing it for taking the

ALTITUDE of the SUN, MOON, and STARS,

FOR FINDING THE

LATITUDE AT SEA.

Illuſtrated by COPPER PLATE FIGURES.

TO WHICH IS ADDED,

Correct TABLES of the SUN'S DECLINATION,

WITH A

TABLE of the VARIATION of the SUN'S DECLINATION In different LONGITUDES,

A TABLE of REFRACTION, &c. &c.

LONDON:

Printed for GREGORY and WRIGHT, Mathematical Inſtrument Makers, near the *India Houſe*, *Leadenhall-Street*.

The THEORY *and Uſe of* HADLEY'S QUADRANT *demonſtrated.*

IT is not to be ſuppoſed that any Perſon can underſtand the Uſe of any optical inſtrument whatſoever, who is not acquainted with the *firſt Principle* (or rather *Axiom*) of OPTICS, *viz.* That in Caſe of Light falling on, and reflected from any poliſhed Surface, or *Speculum*, *the Angle of Incidence is ever equal to the Angle of Reflection.*

This Principle is demonſtrated by *Writers* on OPTICS, both from Reaſon and Experiment, and is eaſily illuſtrated by Figure firſt.

Let E F be a Speculum, or plain Looking-glaſs, on which a Ray of Light S D falls in the Point D: then if the Line P D be perpendicular to the Glaſs in the Point D; and make the Angle P D O equal to the Angle P D S, the Line D O will be the *reflected Ray*; and in all Caſes the *Angle of Incidence* S D P *will ever be equal to the Angle of Reflection* P D O.

If D M be an Index fixed at Right-angles to the back Part of the Speculum F E in the Point D, it will then be in the Direction of the Perpendicular P D; and ſuppoſing the incident Ray S D continued from D to L, then by inclining or moving the Index D M towards D L, the Glaſs F E will have the ſame Motion on the Point or Center D, and at Length arrive to the Situation A B, during which Time the Perpendicular P D will gradually approach to the incident Ray S D, and, at laſt, coincide with it.

But as the Perpendicular P D approaches the Ray S D, the Angle of Incidence P D S is conſtantly decreaſing. and therefore, alſo, the Angle of Reflection P D O, which is always equal to it. And when P D coincides with S D, or D M with D L. then both theſe Angles vaniſh; and the incident Ray is reflected back upon itſelf, or in the ſame Perpendicular Direction from D to S.

In the Time the Perpendicular P D moves through the Arch P S, the reflected Ray D O moves through the Arch O S, which is double the Arch P S. Therefore the Motion of the reflected Ray O D is twice as quick as the Motion of the Perpendicular P D, or of the Index D M, or of the Glaſs itſelf F E.

Again let A B (Fig 2,) repreſent the large Glaſs of *Hadley's Quadrant*, moveable about the Center C of the Inſtru-

 ment,

ment, by means of the Index on which it is fixed; and let P C be Perpendicular thereto in the Point C; then if a Ray of Light, as H C, fall upon it in the Point C, it will be so reflected as to make the Angle of Incidence H C P equal to the Angle of Reflection P C G; and therefore, by describing on the Center C the Circle M G L, and making the Arch P G equal to P H, the Line C G will be the reflected Ray.

For, let F be the smaller Glass in a position F N, parallel to that of the larger one A B, and suppose F Q Perpendicular thereto; then, again, the Ray of Light C G falling on this Glass in the Point F, will be so reflected, that the Angle C F Q will be equal to the Angle Q F I, if F I be the reflected Ray.

Now because the two Glasses A B, and F, are in a parallel Position, therefore the Perpendiculars P C and F Q will also be parallel; therefore the right Line C F which crosses them in C and F will make the alternate Angles P C F and C F Q equal; and consequently, the Angle H C P will be equal to the Angle Q F I, which proves *that the Ray* F I, *after two Reflections, is parallel to the incident Ray* H C.

Hence it follows, that in all positions of the Quadrant (while the Glasses remain parallel to each other) the Eye at I will view any very distant Object in the same Place by the reflected Ray F I, as it would do by the incident Ray at O, if the Glass A B were removed. Hence the Reason of adjusting the Quadrant by a *distant Object*, either the Horizon itself, or any other remote Object, since in such a Case, the Object seen by the direct Ray H C, and the Image shewn by the reflected Ray F I do coincide, or appear in one and the same Place.

But this will not be the Case when the Object is so near, that the Line or Distance C S subtends at the Object a sensible Angle, because then the Incident and reflected Rays H C and F I intersect each other; and therefore the object and Image, in the Glass at F, will appear in two different Places.

If the position of the small Glass (Fig 3.) F be Perpendicular to that of the large Glass A B, or T F N perpendicular to A B D, and the Line Q F perpendicular to the said Glass in F; then the Angle H C P is equal to the Angle P C F, as before; and also the Angle C F Q is equal to the Angle Q F I; therefore the Angle C F N is equal to the Angle I F T; but T N is parallel to P C; therefore the Angle C F N is equal to the Angle F C P, and also to the Angle P C H; consequently the Angle T F I is equal to the Angle P C H. But T F is parallel to P C, therefore the reflected Ray I F is parallel to the incident Ray H C. Wherefore the Image of an Object, at a great Distance, is seen at R, by an Eye at I in the same right Line with the Object itself, but in an

an opposite Part of the Hemisphere; which gives the Reason, *why the Second, or lowermost of the small Glasses is placed in that Position on the Side of the Quadrant for the Back-observation.*

If while the Glass F retains its Position (as in Fig 2.) the large Glass A B be moved on the Index from its parallel Position in A D to any other as A X (Fig. 3.) then while the Index C X describes the Angle D C X, the Perpendicular P C will describe the equal Angle P C *p*. In this Situation of the Glasses, let M C be the incident Ray, and F I the last reflected One, produce M C till it intersects the reflected Ray in I; then will the Angle M I F be equal to twice the Angle D C X.

For in this Case the Angle by the first Reflection is increased from G C H to GCM, by the excess H C M; but the Half the Angle G C M is G *Cp*, and its Excess above G C P (the Half of G C H) is the Angle P *Cp*; therefore the whole Excess H C M of the whole Angle G C M above G C H must be equal to twice the Angle P C *p*, or twice the Angle D C X; but since H O is parallel to F I, the Angle M C H is equal to the Angle M I F; *consequently the Angle* M I F, *is equal to double the Angle* D C X; *therefore the Angle* M C H (equal to M I F) *is also double the Angle* D C X.

Or thus; since the Glass F is immoveable, and also the Point C, which is the Center of the moveable Glass A B; it is easy to understand that the Rays C F and F I will each of them be fixed; and therefore the Ray C F may be considered as falling on the Glass A B in the Point C, and thereby reflected in the direction C M; but C M, considered as the reflected Ray, has twice the Motion of the reflecting Glass A B, or its Index A X; that is, while the Index moves from D to X, the Ray is reflected from H to M, and the Arch H M is double the Arch D X, as we shewed in the Beginning was always the Case in a single Reflection.

It now appears by Demonstration, that by moving the Index over any Number of Degrees on the Limb of the Quadrant, you measure an Arch in the Heavens just equal to twice that Number of Degrees. And therefore the *Octant*, or *eighth Part* of a Circle, is, by this Construction, rendered equivalent to a *Quadrant* or *fourth Part* of a Circle for measuring Angles.

But the greatest Advantage of this Instrument, and by which it excels all others for Sea-use, consists in this, *that the Image of an Object, by the second Reflection, is quiescent, or at Rest while the Quadrant is in Motion*; I mean that Motion which is made in a vertical Plane passing through the Object. For let the Instrument have what Position it will in that Plane, the Angle M I F is not thereby affected or altered, and consequently the Position of the last reflected Ray is the same, and therefore

therefore the apparent Place, or Image of the Object, must necessarily be invariable, or at rest.

To demonstrate this in the easiest Case, we need only consider, that as the Quadrant moves on the Point C, or Axis of the Glass A B (Fig. 2.) the Perpendicular P C will be carried to, or from the fixed Line H O, and thereby the Angle P C H becomes diminished or encreased; but the Angle P C F will ever be equal to P C H; and because the Perpendicular Q F is always (in this Case) parallel to P C, therefore the Angle C F Q is equal to P C F; and consequently C F I is always equal to F C H; therefore the reflected Ray F I is parallel to H C constantly, and will of Course shew the Object ever in the *same Place*, or *at Rest*. The Reasoning is the same for Fig. 2, and 3, or any other Position of the Glasses, provided they are parallel to each other when the Index is at the Beginning of the Degrees on the Limb of the Quadrant.

If the Quadrant liberates sideways, or has a Motion contrary to the former, there will, indeed, be a Motion of the Image produced, because, since the Image is always formed in the Plane of Reflection, which passes through the Object and the Fye of the Spectator; it is evident, if that Plane be changed, the Place of the Image must change with it, and a Motion of the Image will be the effect of such a Motion of the Instrument. But then this Motion is so far from being detrimental, that on the contrary, it is of very great Use in many Cases, which the Mariner very well knows.

These are all the essential Particulars which constitute the Nature and Teeory of this capital Instrument; the Form of which as it is fitted for Use, with a *Nonius*, is that in Fig. 5.

The Quadrant thus finished being applied in the usual Manner to take Altitudes by reducing all celestial Objects to the Level or *Edge of the Sea*, which I call the *Marine Horizon*, in Contradistinction to the *true* or *natural Horizon*.

To explain this Matter (Fig. 6.) let A B D be a Part of the Surface of the Sea; C, the Center of the Earth; A C, its Semidiameter equal to 43946552 *English* Feet. Then if A H be any Height to which the Eye is elevated above the Surface of the Sea at A, and through the Point H you draw H O perpendicular to H C, that Line H O will be the *true Horizon*: and if from the Point H you draw H E to touch the Surface of the Sea in some Point B; then is the Line H E the *Marine Horizon*, or that which appears to the Eye. Lastly, the Angle contained between the two, *viz.* the Angle O H E is called the *Dip of the Marine, or visible Horizon.*

Hence, when the Altitude of the Sun or Star at S is taken by the Quadrant, the Angle measured on the Limb is S H E, greater than the true Altitude S H O, by the said Dip, or

Angle

Angle O H E, which therefore muſt be ſubducted from the meaſured Altitude in the *fore Obſervation*

The Quantity of the Dip, or Angle O H E is computed from the Triangle B C H, right angled at B, in which the Side B C is known, and alſo the Side C H when the Height of the Eye A H is given.

Beſides this, there is another Correction of the apparent Altitude of Objects meaſured by the Quadrant; for by Reaſon of the Refraction of Light through the Atmoſphere, or Body of Air, the Places of all Bodies are raiſed higher above the Horizon than what they really are; ſo that ſuppoſe S the true Place of the Sun or Star, its apparant Place will be at I by this Refraction of the Air. And it is the Angle or Arch G E which is meaſured by the Inſtrument, and not the Arch F E, which is the real Altitude above the Sea; and therefore from the meaſured Arch G E we ſubtract on one Hand the Dip of the Marine Horizon O E; and on the other, the Arch F G, the Quantity of Refraction; and then we get the Remainder F O for the true Altitude required, of the Object at S.

If we have Regard to the Zenith Diſtance Z F of the Object S, it is plain, that is made leſs by Refraction, being only Z G; therefore the Arch F G is to be added to the apparent or meaſured Zenith Diſtance to have the true Zenith Diſtance Z F, of the Sun or Star at S.

The more obliquely the Rays fall on the Atmoſphere, the greater will be the Refraction, and conſequently the horizontal Refraction will be greateſt of all, and at the Zenith, where the Rays are perpendicular there will be no Refraction at all. The Altitude obſerved, muſt therefore be corrected by a Table of Refraction, you will find in the Book.

Deſcription *and* Uſe *of the* OCTANT, *when complete as* Fig. 5.

THIS inſtrument is made from 4 to 18 inches radius: The parts of which are,

The Index D.
The Index-Glaſs I.
The Horizon-Glaſſes B. F.
The Screens H, H.

The ſight vanes EE, and the graduated arch AC, which contains only the eighth part of the circumference of a circle, or 45 degrees, divided into 90 primary diviſions, which by the laws of Catoptrics, anſwer to degrees, (as before obſerved) and are numbered 0, 10, 20, &c. to 90. Each degree is divided into

into 3 parts of 20 minutes each, which, by the help of the Nonius, or Vernier's ſcale, are ſubdivided into minutes of a degree.

The INDEX D.

Is a flat rod or bar, moveable on the centre of the inſtrument, and that part of the index, which ſlides over the graduated arch AC, is open in the middle to ſee the diviſions cut by the Nonius; by the help of which an angle or altitude may be meaſured to a minute. On the bottom of the index, againſt the back of the arch, there is a ſcrew to keep the index faſt when required.

The INDEX-GLASS I

Is a piece of glaſs, truly ground, ſilvered on the back, and ſet in a braſs frame. The uſe of this glaſs is to receive the rays coming from an object, and to reflect them to the horizon-glaſſes. Behind this glaſs are ſcrews to ſet it perpendicular to the plane of the inſtrument.

The HORIZON-GLASSES B,F.

Are ſmaller pieces of ground glaſs, one part of which is ſilvered (the other part left tranſparent to view an object direct) ſet in frames, and placed on the limb at B and F, to receive the rays of an object reflected from the index-glaſs, and to reflect it again to the eye, looking through the holes in the ſight vanes. Both theſe glaſſes are mounted on adjuſting plates with ſcrews, by which the glaſſes may be adjuſted when neceſſary. F is uſed for a fore-obſervation, and B for the back-obſervation.

The SCREENS H,H.

Are pieces of coloured glaſs, ground and ſet in frames; their uſe is to take off the glare of the ſun's rays, when too ſtrong for the eye.

The SIGHT VANES E,E.

Are two pieces of braſs ſtanding perpendicular to the plane of the inſtrument; the vane for the fore-obſervation has two ſmall holes in it: the inner one for more readily viewing the reflected image of ſtars, or faint objects, on the edge of the ſilvered part of the horizon-glaſs; the other for viewing the image of the ſun, when bright, from the poliſhed ſurface of the unſilvered part.

The Nonius, or Vernier, is a ſmall piece of ſloping, or feather-edged ivory, braſs or box-wood, graduated and faſtened to the bottom of the opening of the index; but often the lower part of the opening is graduated for the Nonius, which is numbered thus, 10—15—0—5—10; or thus, 10—15—△—5—10; ſometimes thus, 20—15—10—5—0, and ſlides upon the graduations of the arch.

The

The arch, as before obſerved, is divided into 90 degrees, numbered 10, 20, 30, &c. and each degree into 3 parts, each 20 minutes, and is to be read thus: 1d.—1d. 20m.—1d. 40m. 2d.—2d. 20m.—2d. 40m.—3d. &c. obſerving to read to the diviſion that the o, or diamond-like point, of the Nonius laſt paſſed over; then the Nonius will give the number of minutes more, to be added to the diviſion laſt paſſed by the Nonius. Thus, ſuppoſe the o, or △ of the Nonius has paſſed over 12 degrees and two parts, or 12d. 40m. and ſtands ſomewhere between 12d. 40m. and 13d. then obſerve what diviſion or line on the Nonius coincides with any diviſion or line on the arch, that number on the Nonius will be the minutes to be added to 12d. 40m. Suppoſe 15 on the Nonius touches ſome diviſion on the arch, then 15m. muſt be added to 12d. 40m. and the angle or altitude meaſured will be 12d. 55m.

N. B. No two lines on the Nonius, except the two tens, can exactly coincide with the lines on the graduated arch, if the inſtrument be well divided.

This inſtrument, though it come perfectly adjuſted from the maker's hands, which is not always the caſe, is liable to be put out of order by many accidents, ſuch as lying in the ſun; and the ſpray of the ſea cauſing it to warp, or expanding and conrtacting the frame; ſometimes a fall, &c. It is therefore neceſſary, that the mariner ſhould be able to verify and re-adjuſt the ſeveral parts of his inſtrument at ſea.

Firſt, the index-glaſs muſt be perpendicular to the plane of the quadrant, which, if not, will be eaſily diſcovered by the following method: Hold the plane of the quadrant in an horizontal poſition, with the index-glaſs near the eye; look right down the quadrant, in ſuch a manner as to ſee the arch of the quadrant direct, and at the ſame time reflected, by the index-glaſs, then if the reflected image, and the arch ſeen direct, make as it were but one plane, the glaſs is perpendicular to the plane of the inſtrument; on the contrary, if the arch and its reflected image do not appear to make one continued right plane, it ſhews the index-glaſs muſt have an inclination, and this muſt be rectified by the adjuſting ſcrews behind the frame of the index-glaſs. It is eaſy to diſcover which way the inclination is, by preſſing the index-glaſs with your thumb while you obſerve the arch.*

Secondly, the axis of the horizon-glaſſes muſt be parallel to the axis of the index-glaſs, if not, the error is eaſily diſcovered and rectified in the fore horizon-glaſs, when the index-glaſs is adjuſted. Thus, bring o on the Nonius nearly to o on the graduated arch, and look directly through the ſight vane

* This accurate method of adjuſting the index glaſs at all times at Sea, was communicated to me by Mr. John Adams, Teacher of the Mathematicks at Edmonton.

vane at the moon, or any bright ſtar, ſo as to ſee the reflected image in the horizon-glaſs, and the object, at the ſame time, through the unſilvered part; then move the index backwards and forwards ſlowly, and obſerve if the image and the object paſs directly over each other, if they do, the axes are parallel; but if one paſs to the right, and the other to the left, then put your thumb upon the horizon-glaſs, and preſs it a little, looking ſtill at the object, and you will immediately ſee which way it wants to be adjuſted, and may adjuſt it accordginly by the ſcrews on the adjuſting plate. This is a nice, though very neceſſary adjuſtment, and requires care and patience, for a ſmall turn of the ſcrews will cauſe a conſiderable variation in the axis.

I would adviſe the mariner to have a ſmall piece of coloured glaſs, ſet in braſs, to ſlide over the ſight vane occaſionally, to guard the eye, and then this verification may be commodiouſly made by the ſun as well as the moon or ſtar; for the ſcreens muſt be turned back, that the object and reflected image may be ſeen nearly equally diſtinct; Or a coloured glaſs fixed in a frame, to turn up againſt the back of the horizon-glaſs (which is commonly fixed to ſectants) will have the ſame effect.

Thirdly, The index error. This adjuſtment is well known by thoſe who uſe this inſtrument. The common mode of performing it is thus, bring o on the Nonius exactly to o on the arch, then looking directly through the ſight vane at the horizon; if the reflected horizon appear in the horizon-glaſs, higher or lower than the horizon ſeen directly through the unſilvered part; you then, by moving the braſs lever fixed at the back of the inſtrument to the horizon-glaſs, bring both the reflected and direct horizon to appear as but one line. Theſe three adjuſtments being made, the inſtrument is completely rectified or adjuſted for any obſervation.

The index error may be more accurately determined thus: ſlide on the coloured glaſs before mentioned upon the ſight vane, put the ſcreens back, and meaſure the diameter of the ſun, that is, bring the upper limb to coincide with the lower, if it meaſure 32 minutes * there is little or no index error; but if it meaſure leſs, add the difference to any angle you meaſure; if more, ſubtract the difference from any angle you meaſure, the ſum, or difference reſpectively, will be the true angle or altitude.

EXAMPLE.

Suppoſe the ſun's diameter meaſures 28 minutes, and the altitude taken by the inſtrument be 34d. 10m. then add the error 4m. (the difference between 32m. and 28m. the altitude will

* The ſun's diameter in January is about 32 minutes and half, in July about 31 minutes and half, and in April and October 32 minutes nearly.

will be 34d. 14m. but had the diameter meaſured 36m. then the difference 4m. muſt have been ſubtracted, and the altitude would be 34d. 6m.

To take an Altitude of the Sun by the fore Obſervation.

The ſun is generally bright enough to be ſeen by reflection from the poliſhed ſurface of the unſilvered part of the horizon-glaſs; therefore look through the outer hole in the ſight vane, having put one of the ſcreens down in its place to guard the eye. Hold the inſtrument vertical, and turning yourſelf towards the ſun, direct the ſight to that part of the horizon which is under the ſun; then move the index forwards 'till you ſee the red image of the ſun come down towards the horizon. If you meet with any difficulty in finding the red image of the ſun turn the ſcreen back, and the ſun's image will be ſo bright you cannot miſs it; and you may then put the ſcreen in its proper place again. Having brought the image down near to the horizon, ſwing the octant backward and forwards, making your eye the centre of motion, moving the index forward at the ſame time, 'till the lower limb of the ſun juſt ſweeps the horizon, and you will have the apparant altitude of the ſun's lower limb upon the arch of the quadrant at that inſtant. But the meridian, or greateſt altitude, is that, from which the latitude is to be determined, which is exactly at noon or 12 o'clock. Now, if you have adjuſted your watch by an altitude of the ſun, and have not failed conſiderably to the Eaſtward or Weſtward, you may know exactly when to take the meridian altitude. But ſuppoſing you have ſailed a degree directly Eaſt or Weſt, it will make but 4 minutes difference between your watch and the ſun, and much time may be ſaved in waiting to obſerve the greateſt altitude; beſides your inſtrument will not be ſo long expoſed to the weather and ſun, as is too commonly the caſe. Having found the apparent altitude of the ſun's lower limb, the following corrections muſt be applied:

Firſt. The index error, if any, to be added or ſubtracted, as taught in the third correction of the inſtrument.

Secondly. The dip of the horizon to be ſubtracted.

Thirdly. The ſun's ſemidiameter 16 minutes, nearly to be added.

Theſe three corrections give the apparant altitude of the ſun's centre, to which apply the correction for refraction, and you will have the true altitude of the ſun's centre very nearly, the correction for the ſun's parallex being ſo ſmall, that it may always be neglected.

There being no eaſy practical method, at ſea, to adjuſt the axis of the back horizon-glaſs parallel to the axis of the index-

glaſs;

glafs; therefore, we fuppofe it to be as truly placed by the maker as he can, the following method will fo far verify and adjuft it, as to make it fometimes ufeful when the fore obfervation cannot be had on account of land being in the way, or when a very obfcure horizon for the fore obfervation makes the back obfervation more eligible.*

At any time when you have a clear horizon, both for the fore and back obfervation, take the altitude of the fun's lower limb by the fore obfervation, fix the index, fhift the fcreens to the back horizon-glafs, turn immediately round, and ufe the back fight vane and horizon-glafs; then, if the upper limb of the fun (in the obfervation it will appear to you to be the lower limb) appear to fweep the horizon, the back horizon-glafs is true; if not, adjuft it by its lever. Repeat this feveral times near noon when the fun does not rife or fall very faft; thus your inftrument will be nearly adjufted, and ready for an obfervation when requifite.

The back obfervation is managed exactly in the fame manner as the fore obfervation, only the back muft be turned towards the fun, the fcreens fhifted to that horizon-glafs, and the femidiameter of the fun muft be fubtracted (if the apparent lower limb be taken) and the dip added, to find the apparent altitude of the fun's centre; from which fubtract the effect of refraction, and you will have the true altitude nearly.

There is generally a fmall piece of brafs, fixed to ftop the index where o on the Nonius fhould coincide with o on the arch, which is feldom placed exact; I would therefore advife the mariner to turn it down out of the way, and truft to his own care in the correction of his inftrument; befides, if this be away, the correction may be very accurately eftimated by taking the diameter of the fun, moon, or any object before and behind o on the arch; that is, firft bring the upper limb of the object to coincide with the lower, and note the angle; then take it on the extra arch, as it is called, that is, bring the lower limb to coincide with the upper, and note the angle: Half the difference of thefe two angles will be the true correction of the index error.

EXAMPLE.

Suppofe the moon's diameter meafures 35m. on the arch, and 28m. on the extra arch, the difference is 7m. half of which is $3\frac{1}{2}$m. to be fubtracted for the error, becaufe the diameter meafures more on the arch, or gives the moon's diameter too much; but had the extra arch given the greater angle, the error would have been additive.

* By the improvement I have lately made to my Patent Octant, the back obfervation is adjufted in the manner of a fore one, and alfo rendered as eafy in its ufe; a defcription of which I have publifhed as an Appendix to this Book.

 To

To take the Altitude of the Moon.

The moon's altitude may be taken either by the fore or back obſervation, exactly in the ſame manner as the ſun's altitude, only here you muſt bring that edge of the moon into contact with the horizon, which is round and well defined, whether that be the upper or under edge. The corrections to be applied to the obſerved altitude are as follow:

Firſt. The index error, as before directed.

Secondly. The dip to be ſubtracted in the fore obſervation, but added in the back obſervation.

Thirdly. Semidiameter, to be found in the Nautical Ephemeris for every noon and midnight at Greenwich. If very great accuracy is required, this ſemidiameter muſt be corrected for the intermediate time and for the altitude by the rule in page 16, of the tables belonging to the Nautical Ephemeris.

Fourthly. Refraction, to be found and applied as before.

Fifthly. Parallax. The moon's horizontal parallax for every noon and midnight at Greenwhich, is to be found in the Nautical Ephemeris. When nicety is required, this muſt be corrected for all intermediate times by the rule in page 16, of the Requiſite Tables belonging to the Ephemeris. The moon's horizontal parallax being thus obtained, the moon's parallax in altitude may be found therefrom, by page 16 of the tables aforeſaid, and is to be added.

To take the Altitude of a ſtar by the fore Obſervation.

Set the index at 0, and, holding the plane of the octant vertical, direct the ſight to the ſtar, and at the ſame time look for the reflected image of the ſtar in the ſilvered part of the horizon glaſs. Move the index a little, which will ſeparate the reflected image from the direct image; the former will be eaſily diſtinguiſhed from the latter by its motion when you firſt move the index, and as you advance the index, at the ſame time follow the reflected image of the ſtar with your eye, directing the ſight lower and lower, and changing the poſition of the octant as the image of the ſtar deſcends, till you have brought it down to the horizon: the index will then ſhow the obſerved altitude of the ſtar.

The corrections to be applied to the obſerved altitude o a ſtar are firſt the index error. Secondly the dip. Theſe two give the apparent altitude. Thirdly, the refraction, which gives the true altitude. The fixed ſtars have neither ſemidiameter nor parallax.

In

In taking the altitude of a ſtar or the moon by night, always get as near the water as poſſible. In eaſy weather a *grating* may be ſlung over the ſhip's ſide, and the obſerver ſit upon it to take the altitudes. The ſame may be done to take the altitude of the ſun in a hazy horizon, for the nearer the eye is to the ſurface of the water, the nearer the true horizon will be to the eye.

Rules for finding the Latitude from the SUN's ZENITH, DISTANCE *and* DECLINATION *at Noon given.*

THE SUN's Declination admits of two Denominations, that is, North and South. So likewiſe does the Sun's Zenith Diſtance, for the Sun comes to the Meridian either northward or ſouthward of the Zenith. The Latitude alſo admits of the ſame Variation in its Denomination. This being premiſed, the following Rules may be eaſily underſtood.

RULE. I. If the Zenith Diſtance and Declination are of different Denominations, their Sum will give the Latitude whoſe Denomination will be the ſame as that of the Declination.

RULE II. If the Zenith Diſtance and the Declination are both of the ſame Denomination, their Difference will give the Latitude, whoſe Denomination will be the ſame with that of the Zenith Diſtance and Declination, if the Declination is greater then the Zenith Diſtance. But if the Zenith Diſtance is greateſt, the Latitude will be of a contrary Denomination.

The two following Rules ſerve to find the Latitude of the Place from the Altitude and Declination at Noon given.

RULE III. If the Altitude and Declination are of different Denominations, add 90 Degrees to the Declination, and from that Sum ſubtract the Altitude; the remainder is the Latitude of the ſame Denomination as the Declination.

RULE IV. If the Altitude and Declination are of a like Denomination, add the Declination to the Altitude, and ſubtract that Sum from 90 Degrees; if it be leſs, the remainder will be the Latitude of a contrary Denomination. But if it exceeds 90 Degrees; that exceſs will be the Latitude, whoſe Denomination will be the ſame as that of the Altitude and Declination.

DEGREES

DEGREES OF LONGITUDE.

Daily Varia.	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
Min.	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
2	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
4	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2
5	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2
6	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	3
7	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3
8	0	0	1	1	1	1	1	2	2	2	2	3	3	3	3	3	4
9	0	0	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4
10	0	1	1	1	1	2	2	2	3	3	3	3	4	4	4	4	5
11	0	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5
12	0	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6
13	0	1	1	1	2	2	2	3	3	4	4	4	5	5	5	6	6
14	0	1	1	2	2	2	3	3	3	4	4	5	5	5	6	6	7
15	0	1	1	2	2	3	3	3	4	4	5	5	5	6	6	7	7
16	0	1	1	2	2	3	3	4	4	5	5	5	6	6	7	7	8
17	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	7	8
18	1	1	2	2	3	3	4	4	5	5	6	6	7	7	7	8	9
19	1	1	2	2	3	3	4	4	5	5	6	6	7	7	7	8	9
20	1	1	2	2	3	3	4	4	5	6	6	7	7	8	8	9	9
21	1	1	2	2	3	4	4	5	5	6	6	7	8	8	9	9	10
22	1	1	2	2	3	4	4	5	6	6	7	7	8	9	9	10	10
23	1	1	2	3	3	4	4	5	6	6	7	8	8	9	10	10	11
24	1	1	2	3	3	4	4	5	6	7	7	8	9	9	10	11	11

The ſun's declination in the following tables being calculated for the meridian of *London*, if you ſhould be conſiderably to the Eaſtward, or to the Weſtward of *London*, it will cauſe ſome alteration; to correct which, the above Table of variation of the ſun's declination to every 10 degrees of Longitude is to be uſed, as follows:

Firſt, Look out the declination for the given day of the month, and for the day following it, and ſubtract the leſs from the greater, the remainder is the daily variation.

Second, Obſerve whether the declination be increaſing or decreaſing which you may know thus; if the declination for the day following given day be biggeſt, then it is increaſing; but if it be leſs, it is decreaſing,

Third, Look for the daily variation in the firſt column of the table, and ſee what number ſtands right againſt it, and under the given degrees of longitude, which number is to be uſed as follows.

If the difference of longitude be Easterly, and the declination increasing, it must be subtracted from the declination found in the tables for the given day; but if the declination be decreasing, it must be added.

If the difference of longitude be Westerly, and the declination, increasing, it must be added; but if the declination be decreasing, it must be subtracted; the sum in one case, and the remainder in the other will be the sun's declination at noon in the longitude required.

A Table

A TABLE *of the Sun's Declination, for the* FIRST *Year after* LEAP *Year.*

	S.	S.	S.	N.	N.	N.	N.	N.	N.	S.	S.	S.
Days	Jan.	Feb.	Mar.	April	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.
1	23 00	16 54	7 24	4 43	15 13	22 8	23 8	17 59	8 10	3 20	14 36	21 55
2	22 54	16 41	7 1	5 6	15 31	22 16	23 4	17 44	7 49	3 44	14 55	22 4
3	22 48	16 23	6 38	5 29	15 48	22 23	22 59	17 28	7 27	4 7	15 14	22 13
4	22 42	16 5	6 15	5 52	16 5	22 30	22 54	17 12	7 5	4 30	15 33	22 21
5	22 35	15 46	5 52	6 15	16 23	22 37	22 48	16 56	6 42	4 54	15 51	22 29
6	22 28	15 28	5 29	6 37	16 40	22 43	22 42	16 39	6 20	5 17	16 9	22 36
7	22 20	15 10	5 6	7 0	16 56	22 49	22 36	16 22	5 57	5 40	16 27	22 43
8	22 12	14 51	4 42	7 22	17 13	22 55	22 29	16 5	5 35	6 3	16 44	22 49
9	22 4	14 31	4 19	7 45	17 29	23 0	22 22	15 48	5 12	6 26	17 1	22 55
10	21 55	14 12	3 55	8 7	17 44	23 5	22 15	15 31	4 49	6 48	17 18	23 0
11	21 45	13 52	3 32	8 29	18 0	23 9	22 7	15 13	4 26	7 11	17 35	23 5
12	21 35	13 32	3 8	8 51	18 15	23 13	21 58	14 55	4 3	7 34	17 51	23 10
13	21 25	13 12	2 44	9 13	18 30	23 16	21 50	14 36	3 40	7 56	18 7	23 14
14	21 14	12 51	2 21	9 34	18 44	23 19	21 41	14 18	3 17	8 19	18 23	23 17
15	21 3	12 31	1 57	9 55	18 59	23 22	21 31	13 59	2 54	8 41	18 38	23 20
16	20 52	12 11	1 33	10 17	19 13	23 24	21 22	13 40	2 31	9 3	18 53	23 23
17	20 40	11 50	1 10	10 38	19 26	23 26	21 11	13 21	2 7	9 25	19 8	23 25
18	20 28	11 28	0 46	10 59	19 39	23 27	21 1	13 2	1 44	9 47	19 23	23 27
19	20 15	11 6	0 22	11 20	19 52	23 28	20 50	12 42	1 21	10 9	99 37	23 28
			N									
20	20 2	10 45	0 1	11 40	20 5	23 29	20 38	12 22	0 57	10 31	19 50	23 29
21	19 49	10 23	0 25	12 1	20 17	23 29	20 27	12 2	0 34	10 52	20 4	23 29
22	19 35	10 1	0 49	12 21	20 29	23 29	20 15	11 42	0 11	11 13	20 17	23 29
									S			
23	19 21	9 39	1 12	12 41	20 41	23 28	20 3	11 22	0 13	11 34	20 29	23 28
24	19 6	9 17	1 36	13 1	20 52	23 27	19 51	11 1	0 36	11 55	20 41	23 27
25	18 50	8 55	2 0	13 20	21 3	23 26	19 38	10 40	1 0	12 16	20 53	23 25
26	18 36	8 32	2 23	13 39	21 13	23 24	19 25	10 19	1 23	12 37	21 4	23 23
27	18 21	8 10	2 47	13 59	21 23	23 21	19 11	9 58	1 46	12 57	21 15	23 21
28	18 5	7 47	3 10	14 18	21 33	23 19	18 57	9 37	2 10	13 17	21 26	23 18
29	17 49		3 33	14 36	21 42	23 15	18 43	9 16	2 33	13 37	21 36	23 14
30	17 32		3 57	14 55	21 51	23 12	18 29	8 54	2 56	13 57	21 46	23 10
31	17 15		4 20		22 0		18 18	8 32		14 17		23 6

A TABLE

A TABLE *of the Sun's Declination, for the* SECOND *Year after* LEAP *Year.*

Days	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.
1	23 1	17 2	7 29	4 38	15 8	22 6	23 8	18 2	8 16	3 15	14 32	21 53
2	22 55	16 44	7 6	5 1	15 26	22 14	23 2	17 46	7 53	3 39	14 51	22 2
3	22 49	16 27	6 43	5 24	15 44	22 21	22 59	17 31	7 31	4 2	15 9	22 10
4	22 43	16 9	6 20	5 47	16 1	22 28	22 54	17 15	7 9	4 25	15 28	22 29
5	22 36	15 50	5 57	6 9	16 19	22 35	22 48	16 50	6 47	4 48	15 46	22 26
6	22 29	15 32	5 34	6 32	16 36	22 42	22 43	16 42	6 25	5 11	16 5	22 34
7	22 22	15 13	5 11	6 55	16 52	22 48	22 37	16 26	6 2	5 35	16 22	22 41
8	22 13	14 54	4 47	7 17	17 9	22 53	22 30	16 9	5 39	5 57	16 40	22 47
9	22 5	14 35	4 24	7 39	17 25	22 58	22 24	15 51	5 17	6 20	16 57	22 53
10	21 56	14 16	4 0	8 2	17 40	23 3	22 15	15 34	4 54	6 43	17 14	22 58
11	21 47	13 56	3 37	8 24	17 56	23 7	22 8	15 16	4 31	7 6	17 31	23 4
12	21 34	13 36	3 13	8 46	18 11	23 11	22 0	14 58	4 8	7 29	17 47	23 8
13	21 27	13 16	2 50	9 7	18 26	23 15	21 51	14 40	3 45	7 51	18 3	23 12
14	21 16	12 56	2 26	9 29	18 41	23 18	21 42	14 21	3 22	8 14	18 19	23 16
15	21 5	12 35	2 2	9 50	18 55	23 20	21 33	14 3	2 59	8 36	18 34	23 19
16	20 54	12 14	1 39	10 12	19 9	23 23	21 23	13 44	2 36	8 58	18 50	23 22
17	20 42	11 43	1 15	10 33	19 23	23 25	21 13	13 25	2 13	9 20	19 5	23 24
18	20 30	11 32	0 51	10 54	19 36	23 26	21 3	13 6	1 45	9 42	19 19	23 26
19	20 17	11 11	0 28	11 15	19 46	23 27	20 52	12 46	1 26	10 4	19 33	23 27
20	20 4	10 49	0 4	11 35	20 1	23 28	20 41	12 26	1 2	10 26	19 37	23 28
			N									
21	19 51	10 28	0 20	11 56	20 14	23 29	20 30	12 6	0 39	10 47	20 0	23 29
22	19 37	10 6	0 44	12 16	20 26	23 28	20 18	11 46	0 16	11 8	20 13	23 28
									S			
23	19 23	9 44	1 7	12 36	20 37	23 28	20 5	11 26	0 8	11 30	20 26	23 28
24	19 9	9 22	1 31	12 56	20 49	23 27	19 53	11 5	0 31	11 51	20 38	23 27
25	18 54	9 0	1 54	13 15	21 0	23 25	19 44	10 44	0 55	12 11	20 50	23 25
26	18 39	8 37	2 18	13 35	21 10	23 24	19 28	10 24	1 18	12 32	21 2	23 24
27	18 24	8 15	2 41	13 54	21 20	23 21	19 14	10 34	1 42	12 53	21 13	23 22
28	18 8	7 52	3 5	14 13	21 30	23 19	19 1	9 42	2 5	13 13	21 23	23 19
29	17 52		3 28	14 31	21 39	23 16	18 46	9 20	2 28	13 33	21 33	23 16
30	17 35		3 51	14 50	21 48	23 12	18 32	8 59	2 52	13 52	21 43	23 12
31	17 18		4 15		21 57		18 17	8 37		14 12		23 7

A TABLE

A TABLE *of the Sun's Declination, for the* THIRD *Year after* LEAP *Year.*

Days	Jan.		Feb.		Mar.		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m	d.	m.	d.	m.	d.	m.
1	23	3	17	6	7	35	4	32	15	4	22	4	23	9	18	6	8	21	3	9	14	27	21	51
2	22	57	16	49	7	12	4	55	15	22	22	12	23	1	17	50	7	59	3	33	14	46	22	0
3	22	51	16	31	6	49	5	18	15	40	22	19	23	0	17	35	7	37	3	56	15	5	22	8
4	22	44	16	13	6	26	5	41	15	57	22	27	22	55	17	19	7	15	4	19	15	23	22	17
5	22	37	15	59	6	3	6	4	16	14	22	33	22	49	17	3	6	52	4	42	15	42	22	24
6	22	31	15	37	5	40	6	27	16	32	22	40	22	45	16	47	6	30	5	6	16	0	22	32
7	22	24	15	18	5	17	6	49	16	48	22	46	22	38	16	30	6	7	5	29	16	18	22	39
8	22	15	14	59	4	53	7	11	17	4	22	52	22	32	16	13	5	45	5	52	16	36	22	45
9	22	7	14	40	4	36	7	34	17	21	22	57	22	26	15	56	5	22	6	15	16	53	22	51
10	21	58	14	20	4	6	7	56	17	36	23	2	22	17	15	38	5	0	6	37	17	10	22	57
11	21	50	14	2	3	43	8	18	17	52	23	7	22	10	15	21	4	37	7	6	17	27	23	3
12	21	40	13	42	3	19	8	40	18	8	23	10	22	2	15	3	4	14	7	23	17	43	23	7
13	21	29	13	22	2	56	9	2	18	22	23	14	21	53	14	45	3	51	7	46	17	59	23	11
14	21	19	13	1	2	13	9	24	18	37	23	17	21	44	14	26	3	28	8	8	18	15	23	15
15	21	8	12	40	2	8	9	45	18	52	23	20	21	35	14	7	3	5	8	30	18	30	23	18
16	20	57	12	20	1	45	10	7	19	6	23	23	21	26	13	49	2	42	8	53	18	46	23	22
17	20	45	11	59	1	21	10	28	19	19	23	25	21	16	13	30	2	18	9	15	19	1	23	24
18	20	33	11	37	0	57	11	40	19	33	23	26	21	5	13	10	1	55	9	37	19	15	23	25
19	20	20	11	16	0	33	11	9	19	45	23	27	20	54	12	51	1	32	9	58	19	29	23	27
20	20	7	10	55	0	10	11	30	19	58	23	28	20	43	12	31	1	8	10	20	19	43	23	28
					N																			
21	19	55	10	33	0	14	11	51	20	11	23	29	20	33	12	11	0	45	10	42	19	57	23	29
22	19	41	10	11	0	38	12	11	20	23	23	28	20	21	11	51	0	21	11	3	20	10	23	28
																	S							
23	19	27	9	49	1	1	12	31	20	35	23	28	20	9	11	31	0	2	11	24	20	23	23	28
24	19	12	9	27	1	25	12	51	20	46	23	27	19	56	11	10	0	25	11	45	20	35	23	27
25	18	7	9	5	1	48	13	10	20	57	23	26	19	43	10	50	0	49	12	6	20	47	23	26
26	18	43	8	43	2	12	13	30	21	7	23	24	19	32	10	29	1	12	12	27	20	59	23	25
27	18	28	8	20	2	35	13	49	21	17	23	22	19	19	10	8	1	36	12	48	21	10	23	23
28	18	12	7	58	2	59	14	8	21	27	23	20	19	5	9	47	1	59	13	8	21	21	23	20
29	17	56			3	22	14	27	21	36	23	16	18	51	9	25	2	23	13	28	21	31	23	18
30	17	39			3	45	14	46	21	45	23	13	18	36	9	4	2	46	13	47	21	40	23	14
31	17	22			4	9			21	54			18	21	8	42			14	7			23	9

A TABLE

A TABLE *of the Sun's Declination, for the* LEAP *Years*

1784, 1788, 1792, 1796, 1800, 1804, 1808.

Days	Jan.		Feb.		March		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
1	23	4	17	10	7	18	4	49	15	17	22	10	23	6	17	54	8	4	3	27	14	41	21	57
2	22	58	16	53	6	55	5	12	15	35	22	17	23	4	17	38	7	42	3	30	15	0	22	6
3	22	52	16	35	6	32	5	35	15	53	22	25	22	57	17	23	7	20	4	13	15	19	22	14
4	22	46	16	17	6	9	5	58	16	10	22	32	22	52	17	7	6	58	4	37	15	37	22	23
5	22	39	15	59	5	46	6	21	16	27	22	38	22	47	16	51	6	36	5	0	15	56	22	30
6	22	33	15	42	5	22	6	43	16	44	22	44	22	40	16	34	6	13	5	23	16	13	22	37
7	22	26	15	23	4	59	7	6	17	0	22	50	22	33	16	17	5	50	5	46	16	31	22	44
8	22	17	15	4	4	35	7	28	17	17	22	56	22	27	16	0	5	28	6	9	16	49	22	50
9	22	9	14	45	4	12	7	51	17	33	23	1	22	21	15	43	5	5	6	32	17	6	22	56
10	22	0	14	25	3	49	8	13	17	48	23	5	22	12	15	25	4	43	6	55	17	23	23	1
11	21	52	14	7	3	25	8	55	18	3	23	9	22	3	15	7	4	20	7	17	17	39	23	6
12	21	42	13	47	3	1	8	56	18	19	23	13	21	55	14	49	3	57	7	40	17	55	23	10
13	21	32	13	27	2	38	9	18	18	33	23	17	21	47	14	31	3	33	8	2	18	11	23	14
14	21	21	13	6	2	14	9	40	18	48	23	20	21	38	14	12	3	11	8	25	18	27	23	17
15	21	10	12	46	1	51	10	1	19	2	23	22	21	28	13	54	2	47	8	47	18	42	23	21
16	21	0	12	25	1	27	10	22	19	16	23	24	21	18	13	34	2	24	9	9	18	57	23	23
17	20	48	12	4	1	3	10	43	19	39	23	26	21	8	13	15	2	1	9	31	19	12	23	25
18	20	36	11	43	0	39	11	4	19	42	23	27	20	57	12	56	1	38	9	53	19	26	23	27
19	20	23	11	22	0	16	11	25	19	53	23	28	20	41	12	36	1	14	10	15	19	40	23	28
						N																		
20	20	19	11	0	0	8	11	46	20	8	23	29	20	35	12	16	0	51	10	36	19	54	23	28
21	19	58	10	39	0	42	12	6	20	20	23	28	20	23	11	56	0	27	10	58	20	27	23	29
22	19	44	10	17	0	55	12	26	20	32	23	28	20	12	11	36	0	4	11	19	20	19	23	28
																	S							
23	19	30	9	55	1	19	12	46	20	43	23	27	19	59	11	16	0	19	11	40	20	32	23	27
24	19	16	9	33	1	43	13	6	20	44	23	26	19	47	10	55	0	43	12	1	20	44	23	26
25	19	1	9	10	2	6	13	25	21	5	23	25	19	34	10	34	1	6	12	22	20	56	23	24
26	18	47	8	48	2	30	13	40	21	16	23	22	19	20	10	13	1	30	12	42	21	7	23	21
27	18	32	8	26	2	53	14	3	21	26	23	20	19	6	9	52	1	53	13	3	21	18	23	19
28	18	16	8	4	3	16	14	23	21	35	23	17	18	52	9	31	2	17	13	23	21	28	23	16
29	18	0	7	42	3	40	14	41	21	45	23	14	18	38	9	0	2	40	13	43	21	39	23	11
30	17	43			4	3	14	59	21	54	23	10	18	24	8	48	3	4	14	2	21	48	23	8
31	17	26			4	26			22	2			18	9	8	26			14	22			23	3

A TABLE

A Table of Refractions to be subtracted from the Altitude.

Al. D.	Refract. Min.	Refract. Sec.	Al. D.	Refract. Min.	Refract. Sec.	Al. D.	Refract. Min.	Refract. Sec.
1	27	56	31	1	38	61	0	33
2	21	4	32	1	34	62	0	31
3	16	6	33	1	30	63	0	30
4	12	48	34	1	27	64	0	28
5	10	32	35	1	23	65	0	27
6	8	55	36	1	20	66	0	26
7	7	44	37	1	18	67	0	25
8	6	47	38	1	15	68	0	24
9	6	4	39	1	12	69	0	22
10	5	28	40	1	10	70	0	21
11	4	58	41	1	7	71	0	20
12	4	32	42	1	5	72	0	19
13	4	12	43	1	3	73	0	18
14	3	54	44	1	1	74	0	17
15	3	38	45	0	59	75	0	16
16	3	24	46	0	58	76	0	14
17	3	11	47	0	36	77	0	13
18	3	0	48	0	54	78	0	12
19	2	49	49	0	52	79	0	11
20	2	39	50	0	50	80	0	10
21	2	31	51	0	49	81	0	9
22	2	25	52	0	47	82	0	8
23	2	18	53	0	45	83	0	7
24	2	12	54	0	43	84	0	6
25	2	6	55	0	41	85	0	5
26	2	0	56	0	40	86	0	4
27	1	55	57	0	38	87	0	3
28	1	51	58	0	37	88	0	2
29	1	46	59	0	35	89	0	1
30	1	42	60	0	34	90	0	0

A Table of the Moon's Parallaxes to be added to her Altitude.

Al. D.	Pa. M.	Al. D.	Pa. M.	Al. D.	Pa. M.
1	58	31	50	61	28
2	58	32	49	62	27
3	58	33	49	63	26
4	58	34	48	64	25
5	58	35	48	65	25
6	58	36	47	66	24
7	58	37	47	67	23
8	58	38	46	68	22
9	58	39	45	69	21
10	57	40	45	70	20
11	57	41	44	71	19
12	57	42	44	72	18
13	57	43	43	73	17
14	57	44	42	74	16
15	56	45	41	75	15
16	56	46	40	76	14
17	56	47	40	77	13
18	56	48	39	78	12
19	55	49	38	79	11
20	55	50	37	80	10
21	55	51	37	81	9
22	54	52	36	82	8
23	54	53	35	83	7
24	53	54	34	84	6
25	53	55	33	85	5
26	52	56	32	86	4
87	52	57	32	87	3
28	51	58	31	88	2
29	51	59	30	89	1
30	56	60	29	90	0

APPENDIX.

The DESCRIPTION of a New, Easy, and Accurate Method for adjusting the Back Observation Glass of WRIGHT'S IMPROVED PATENT OCTANT, and the Method of using it in taking the apparent Altitude of the Sun at Sea, and measuring Angular Distances from 0 to 180°.

Fig. 1. IS a representation of the Octant complete in all its parts for use.

A. The reflecting surface of the index glass, which is made of the usual length, and $\frac{9}{10}$ of an inch broad.
The bottom part is covered in front by the brass frame and the reflecting surface is $\frac{7}{10}$ on the back.

B. The fore horizon glass placed as usual.

O. The back horizon glass, now placed under the fore sight vane on the first radius of the Octant I.

C. The sight vane of the fore horizon glass.

D. The sight vane of the back horizon glass.

E. The *three* shades or screen glasses in a brass frame, in the proper place for a fore observation of the sun, &c.

F. A hole made in the frame to receive the screen glasses, when an observation is taken with the back horizon glass in the common way, by turning your back to the sun.

G. A hole in the frame on the farthest radius K, to receive the screen glasses when you take an observation of the sun's altitude by the *new method*, which is, by looking through the lower hole in the sight vane of the back horizon glass, directly at the sun in the line of sight DN, the horizon from behind will then be reflected from the back of the index glass to the horizon glass, and from thence to the eye. See fig. 5.

H. A brass clamp on the upper end of the index; having a milled screw underneath which fastens the round plate to the index when required. See fig. 2.

IK. The graduated arch of the Octant divided into 90 degrees.

L. The brass index which moves over the graduated arch.

M. The Nonius (or Vernier) graduated on the bottom of the index to subdivide the divisions on the arch into single minutes of a degree.

Fig. 2.

Fig. 2. Shews the upper part of the index L on a larger ſcale, with part of the braſs frame that faſtens the index glaſs, and the three adjuſting ſcrews D, to adjuſt its axis verticle to the plane of the Octant, B the center on which the milled plate O moves over the index, the dotted line BF is the diſtance it is required to move, K the adjuſting ſcrew to ſtop it in its proper place for adjuſting the back obſervation glaſs, G a piece of braſs faſtened to the index oppoſite to the clamp H, to keep the plate O always cloſe to the index L.

Fig. 3. Repreſents the parallel poſition of the index and horizon glaſſes after adjuſtment by the ſun, BC a ray from the ſun falling on the center of the index glaſs C, and from thence reflected to D, the center of the fore horizon glaſs, from which glaſs it is again reflected to the eye at E in the line DE, where the eye ſees the ſun at A by direct viſion, and the image by reflection in one; the parallel lines A and B being ſo near to each other, that no apparent angle can be obſerved in the planes of the index and horizon glaſs, when adjuſted by an object at a diſtance.

Fig. 4. Here the index glaſs is removed 45 degrees from the plane of the fore horizon glaſs, and in its proper place for adjuſting the back horizon glaſs parallel to its plane, in the manner of a fore horizon glaſs; this is clearly ſhewn by inſpection of the figure, where all the lines and letters appear exactly ſimilar to thoſe in fig. 3; the only difference is, the parallel lines AB are at a greater diſtance, for reaſons too obvious to mention.

Fig. 5. Here the index glaſs (after the adjuſtment of the fore and back horizon glaſſes) is carried forward by the index on the arch 90 degrees, and makes an angle to the plane of the fore horizon glaſs of 45°, and at right angles to the plane of the back horizon glaſs; the eye at E now ſees the ſun in the horizon at H, reflected by the index and horizon glaſſes from the zenith at Z, the image and object being 90° diſtant, as ſhewn by the vertical and horizontal lines ZA and HA, which meet in A, and form the right-angled triangle ZAH. The back horizon K is now reflected from the back ſurface of the index glaſs C, to the horizon glaſs M, and again from thence to the eye at D, in a right line with the fore horizon F, and 180 degrees from F to K, the lines IK and FD being parallel; now to make an exact contact of the fore and back horizon at F, the index muſt be advanced beyond the 90° on the arch, by

reaſon

reason of the spherical figure of the earth, and the height of the observer's eye above the level of the sea, which is called the *dip*, and is usually allowed for by tables; but it being known to vary very much by the difference of the refraction, which is different in a moist and dry air, it also alters by heat and cold, and many other causes, and is very different in different latitudes, it will therefore be found more correct to get it by actual measurement of the fore and back horizon, by a *back observation* (immediately after taking the sun's altitude) and the arch being a supplement, the excess of 90° will be double the dip.

To adjust the Octant for a Fore Observation.

You first see that the index glass is in its proper place, as shewn by fig. 2, and there made fast by the milled screw at H, the remainder of the adjustment is then managed in every respect the same as the fore observation of a common constructed Hadley's Quadrant, which, when adjusted, the glasses have the position of fig. 3.

To adjust the Back Observation.

Fasten the index to 90° on the arch, and there let it remain; the horizon glass must also remain fast in its place; loosen the screw H, fig. 2, and turn the plate O by the milled edge for the end of the adjusting screw K, to touch against the edge of the clamp M, and see (by observation of a distant object) that the glasses are then parallel as at fig. 3, if they are make fast the screw H, if not, with a screw driver turn the screw K gently to the right or left, to make them perfect, before you fasten the screw.* You then remove the index back to the O which carries the index glass backwards 45° from its adjustment with the fore horizon glass, to a parallel position with the back horizon glass E, fig. 4; if not, adjust the glass E to make them so, while you look through the upper hole in the sight vane D in the line of sight DN, fig. 1, at the sun, moon, or horizon; this done let the index remain at O, and the index glass be returned again to stop at the pin E, its first adjustment with the fore horizon glass, fig. 3, and the Octant is ready for observation by either the fore or back horizon glasses; now make use of the lower hole in the sight vane D, and both occasionally for the fore observation C.

To

* This last adjustment of the screw K we make perfectly correct before the Octants go out of our hands, and from the care in fixing, and the situation it is placed in, it is almost impossible it should alter afterwards, but for fear of accident, I have been thus particular in my directions for adjusting it.

To take a Back Obſervation.

To take a back obſervation of the ſun's altitude, you remove the ſcreen glaſſes to G, fig. 1, and look through the lower hole in the ſight vane D, in the line of direction DN, directly up at the ſun, through the ſcreen glaſs or glaſſes turned down to ſave the eye, and move the index forward on the arch exactly the ſame as for a fore obſervation, and make the contact with the ſun's upper limb and the back horizon, which you now ſee by reflection inverted, and the degrees and minutes by the Nonius on the arch is the zenith diſtance, to which you add the ſun's Semidiameter. *Note.* If you meaſure from the lower limb of the ſun, the ſemidiameter muſt be ſubtracted, and from either the dip is ſubtracted alſo. If you take the obſervation in the uſual way, by turning the back to the ſun, ſhift the ſcreen glaſſes to F, and follow the directions given with the common Hadley's Quadrant, you will take this obſervation much eaſier and better by this Octant than the common ones, for here you keep the Octant in your right hand, and move the index on the arch forwards likewiſe.

The obſerver will take notice, that if the axis of the glaſſes are fixed truly perpendicular to the plane of the inſtrument, that it is not abſolutely neceſſary to have them adjuſted truly parallel in their planes before an obſervation is taken (ſhould there not be time for it) but after the obſervation to find the error if any, by the method now much in uſe by the beſt obſervers, called the Index Error, and deſcribed in the beſt books on the uſe of Hadley's Quadrant.

The Octant may now be ſaid to be univerſal, as it is equally applicable for meaſuring angular diſtances from 90° to 180°, as it before was, from 0° to 90°, and by an artificial horizon made from the reflecting ſurface of quickſilver, or any other horizontal reflecting plane, the altitude of objects on ſhore can always be taken; alſo the ſun's altitude at all times of the year and in all latitudes, which could not be done if the ſun at any time exceeded 60° by the common conſtructed Sextants and Quadrants, the ſurveyor will likewiſe find it the moſt uſeful and beſt adapted inſtrument (if made of a ſmall radius) for his purpoſe.

The price of the Patent Octant, with the above improvements complete, in ebony frames, as repreſented in fig. 1 —	£ 3	13	6
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